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been found over the county. One east of Arrington measures 7½x6 feet, and formerly protruded three feet above the ground. The Agassiz Science Club is keeping a record of the location and dimensions of these boulders, on a map prepared for that purpose. One of the most interesting studies in this section is the glacial drift, which constitutes most of the surface of Atchison county. I have found it varying from a few feet in thickness to over 100 feet. During the past two years arrangements have been made with well borers to collect, in boxes prepared for the purpose, specimens of clay passed through, together with the thickness of the clay beds. This work has not progressed far enough to reach any definite conclusions. The clay lies in sharply separated beds, some of which are very thick. In 1868, Prof. Louis Agassiz, accompanied by Roscoe Conkling and others, visited northeast Kansas. Agassiz recognized in the red, gray, and green boulders on our hills a verification of the glacial theory he had worked out in his native Switzerland, viz., that these boulders were brought here by the ice sheet which about 10,000 years ago covered all the northern part of the northern continents. The ice sheet grated over the surface of the country, scraping up huge boulders and smaller particles from the limestones, granites, and greenstones of Canada and from the red quartzites of Minnesota and Dakota. These boulders were dropped by the melting ice on the prairies.

I have carefully observed this glacial deposit covering northeast Kansas from Kansas City to Junction City and Washington county. I have seen it at West Point and other places up and down the Hudson river; in Central Park, New York city; in the Sierra Nevada mountains, and along the Pacific coast. In fact, the ice sheet sprinkled its boulders and mud on top of the older deposits over all the northern continents as far south as the 39th parallel of latitude.

NOTES ON KANSAS PHYSIOGRAPHY.

By J. W. Beede. Read before the Academy January 2, 1897.

General Outline.

Kansas erosion is from plain to plain rather than from ridge to plain. In other words, the elements have an elevated plain to break up and reduce to a plain of lower elevation, instead of a high ridge to reduce to a base level, as is the case in mountainous regions. At present, the parts under consideration are intermediate forms, varying according to the nature of the rocks of which they are composed and the climatic conditions to which they have been subjected.

In various parts of the state good examples of these intermediate forms of reduction may be seen, modified by climate and structure. The youngest is in the Red Beds, in the more highly developed part, and illustrates an early stage of reduction. The original plain is represented roughly by the more elevated summits, while the valleys and cañons represent the amount of material removed. A more advanced stage of erosion is represented in the eastern extremity of the Dakota formation. Here a slightly different climatic condition has obtained, and there is also a difference of rock structure. It has been subjected to other conditions which are as yet but very little understood. Near the Smoky Hill valley, the Permian shales on which the Dakota rests sink to a lower level than to the eastward or westward, which seems to be due to erosion, producing a marked unconformity. It may indicate a pre-Dakotan drainage channel. Section 3 is in the Carboniferous of eastern Kansas. This is the oldest of the four regions, and has been subjected to the most active erosive agencies, yet its systems of chert-bearing limestone have withstood the degrading influences to a wonderful extent. The Permian shales are practically homogeneous, so far as our purposes here are concerned. In this locality erosion has nearly completed its more active work.

THE RED BEDS.

A section extending from Medicine Lodge in a southwesterly direction across the Salt Fork, Barber county, passes through a highly developed portion of the Red Beds. The elevated summits represent approximately the primal plain.

The climate here is quite arid, and the streams are dry during the greater part of the year. Vegetation is sparse, especially at the heads of the arroyos. Farther down the streams vegetation becomes more abundant, and trees are quite common. On the hillsides the grass is so thin that the red earth may be seen for miles, even in the summer months. The lack of vegetation at the very heads of the streams, where it would retard degradation the most, makes the conditions most favorable for rapid erosion, and has probably played no unimportant part in determining the present topography of the region. Plate IV in the foreground shows the grass only in little bunches far apart, as is the general rule. In the upper part of this formation is a stratum of gypsum 25 feet in thickness. Under this are several hundred feet of soft arenaceous and argillaceous shales and sandstones which seem to be much more easy to erode than the gypsum. The gypsum tends to preserve the original plain, while the rapidly-eroding shales form large, steep escarpments and the "Mansard Buttes" of Professor Hay.* These are illustrated in plate V. The minor streams have not yet reached their base levels and are dry most of the year, corrading their beds only in times of flood, and producing the cañon-like topography peculiar to these conditions. The greater streams have about reached their base levels and are beginning to widen their valleys. As a consequence, there is very little bottom land or high prairie, the country being simply a system of hills and sharp valleys.

Notwithstanding the fact that there are many conditions favorable to erosion, yet through the lack of perennial streams and springs and the uneven distribution of the rainfall in this locality, which comes within a short time in the spring, degradation seems to progress less rapidly than in some other parts of the state. The Medicine Lodge river has cut a fairly wide valley through this formation, and is not corrading its channel to a very great extent at present, but is wearing away its bluffs. Its bed is covered with "quicksand," over which flows a small stream of water.

The Salt Fork flows, largely, in a small cañon in its course through Comanche and Barber counties. Its bed is covered with sand from the Tertiary formation at its head. The smaller streams flow in V-shaped valleys which are often quite deep, and at the heads of which are occasionally semicircular excavations with vertical walls sometimes 40 feet high. These places are sometimes several rods in diameter. On the ridges the ground is nearly level, and these depressions cannot be seen until approached within a few rods. Good examples of this form of an arroyo head may be seen a few miles southwest of Medicine Lodge and on the small tributaries to the north of the Salt Fork, in Comanche county. At the place where the Medicine Lodge river passes through the eastern limit of the gypsum, the gypsum weathers in little outliers between the main bluff and the river, forming round hills capped with gypsum. The side next the river is sometimes 200 feet high and very steep. A series of these may be seen on the south side of the Medicine between Sun City and Lake City, Barber county.

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*Bull. No. 57, U. S. Geol. Surv.

The Dakota Sandstone.

The nature of the eastern extension of the Dakota formation is well represented in Saline county. It illustrates the outlier system of outcrop, which, instead of a connected front, is a system of islands separated from the general mass, sometimes several miles. The material of which this formation is composed is soft shales, and friable, with occasionally harder, sandstones. These rest upon the argillaceous shales of the Permian. The surface of the latter is quite uneven, and is considerably depressed in the vicinity of the valley of the Smoky Hill river, as is represented near Lindsborg. This depression seems to continue north and south, conforming more or less roughly to the valley of the Smoky Hill river in Saline county. The McPherson Equus beds are deposited in a similar but larger depression to the southward, which may be in part a prolongation of this old channel or depression. Just what this old channel has had to do with the present drainage system of this region is hard to tell at present, though it seems to have had some influence upon it.* It may indicate a pre-Dakotan drainage system in this portion of the state.

It seems not impossible that this old drainage system may have connected with the Red Beds sea to the southward. If this is the case it would make the majority of the Red Beds of post-Permian age.† The topography of the region is peculiar to itself. The Smoky Hill buttes stand 400 feet above the Smoky Hill river and 300 feet above the surrounding country. This elevation is composed of Dakota sandstone and shales, and is practically isolated from the main outcrop. Still east of this there are two more islands of less height but far greater areas, which are separated several miles from the main outcrop. The majority of the large streams flow at right angles to main outcrop, while the lesser ones are monoclinal. The lesser streams cut rapidly back into the easily eroded material, and in time cut entirely through the divides, separating the strata into islands disconnected from the main formation. But in making the great valley of the Smoky there seems to have been more than the normal forces at work.* At Mentor the valley is nine miles wide. The great susceptibility of the formation to erosion has caused the work of degradation to progress more rapidly and further than in the Red Beds. Vegetation is more abundant than in the Red Beds, but its influence has not been sufficiently great in comparison to retard reduction to any very marked degree. The streams run at their base levels, or nearly so, and their valleys are fairly wide, in which vegetation is quite luxuriant. The rainfall in this region and the Red Beds have been about the same,‡ the chief difference being in its distribution.

The last trace of the original plain is probably indicated by the Smoky Hill buttes, Iron, Soldier Cap, and North Pole mounds. The eastern portion of this formation is perhaps less developed than the western and shows a great diversity in structure and color, and is highly cross-bedded, and ripple markings are common.

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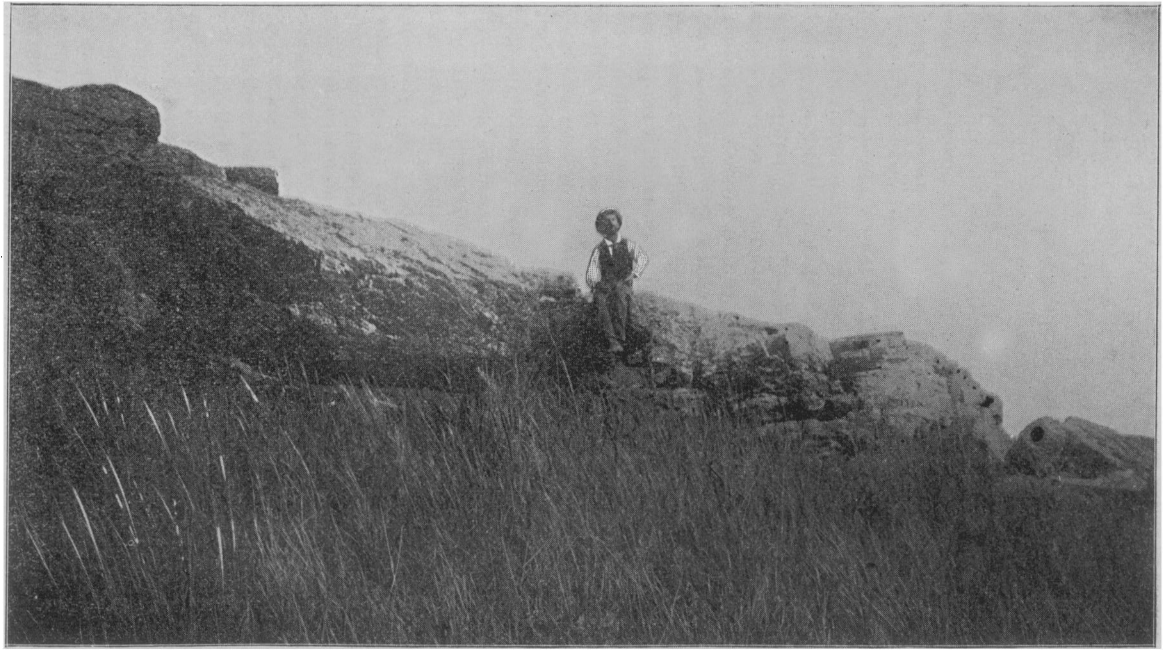
* See article on "McPherson Equus Beds," *ante.*

† Since this was written Dr. S. W. Williston gives an account of the discovery of some Permian vertebrate (*Cricotus collettii* Cope) from Kansas which seems to correlate the lower Permian of Kansas with the Red Beds of Texas. Doctor Williston says: "Above the stratum in which these bones are found are several hundred feet of limestones and shales, above which come the Red Beds of Clark and Comanche counties, which have been variously referred to the Permian and Trias. That this basal Permian fauna continued throughout 800 or 1,000 feet of deposits does not seem probable to me, and I believe yet more strongly, what I always have believed, that the Red Beds of Kansas are Triassic in age. . . ." Kan. Univ. Quar., Vol. VI, No. 1, Jan., 1897, Series A, p. 56.

‡ See Report Board of Irrigation Surv. and Exp., Kan., for 1895 and 1896, p. 195.

PLATE VII.



(From University Geological Survey, Vol. II.)

DAKOTA SANDSTONE AT TOP OF SOLDIER CAP MOUND, SALINE COUNTY.

THE CARBONIFEROUS SHALES AND LIMESTONES.

Plate IX * is from Abilene to Kansas City, along the Kansas river. It crosses the limestone systems exposed in that part of the state, and represents a different topography from the two previous ones. The drainage systems are very old. The larger streams are anaclinal and the smaller ones are monoclinal. Vegetation is abundant on upland and lowland. The streams are perennial and have reached their base levels. Even the small ones are filling their beds with mud. Valley widening has progressed to a considerable extent. Though this section has been exposed to the elements for a longer time than either of the others, yet it presents a surface nearly as rough. Its shales erode easily, it is true; yet the massive chert-bearing limestones resist the agencies of degradation to a wonderful degree. They dip to the west about 10 or 15 feet to the mile. Thus we have a system of high limestone-capped steps as we ascend the Kansas river. The extreme difficulty with which the arroyos corrade their channels in the heavy limestone prevents their being cut into outliers to any considerable extent. As a consequence, the line of outcrop has a very irregular lateral lobing.

The drainage systems here seem to have much the same outline as prior to the Kansas ice invasion, as their present valleys are almost coincident with those prior to the glacial epoch.† They would seem to be older than those of the western portion of the state, as the latter must be younger than the pliocene deposits through which they flow, and the erosion of such extensive valleys in preglacial times, and in such quantities of limestone as these formations in the eastern part of the state contain, must have consumed a considerable time, even under fairly extraordinary conditions. The hills of this region are projecting ridges which vary from 50 to 150 feet in height. The higher are beautifully terraced, especially those on the southern tributaries of Mill creek, in Wabaunsee county, where the upper part of the Wabaunsee, Cottonwood and part of the Neosho formations are present in the same ascent.

The climate is more moist in this than the preceding regions. The heads of the arroyos are more densely covered with vegetation. The agencies of degradation have been more active, and at work longer than in either of the other regions; yet the effect on the surface outline is not very much greater. This difference must be attributed to the combined effect of vegetation and the presence of the limestones, the latter of which is by far the greater, as the discussion of the next locality will demonstrate.

The eastern portion of the section (IX) has been subjected to the abrading influence of the Kansas ice invasion. It will be noticed that there is a slight reduction in the surface when the glaciated region is entered near Willard; yet it is little more than would be expected from the natural results of ordinary erosion.‡ Indeed, if it were not for the materials left by the glacier, it would be hard to discover that there had ever been a glacier south of the Kansas river west of Lawrence.

THE PERMIAN SHALES.

This region is in Sumner county, and the section extends from north of Arkansas City through Geuda Springs west to a place about eight miles northwest of South Haven. Here the surface rock is composed largely of Permian shales which erode quite easily. The long-continued action of erosion has nearly completed its more active work. These shales may be taken as nearly homoge-

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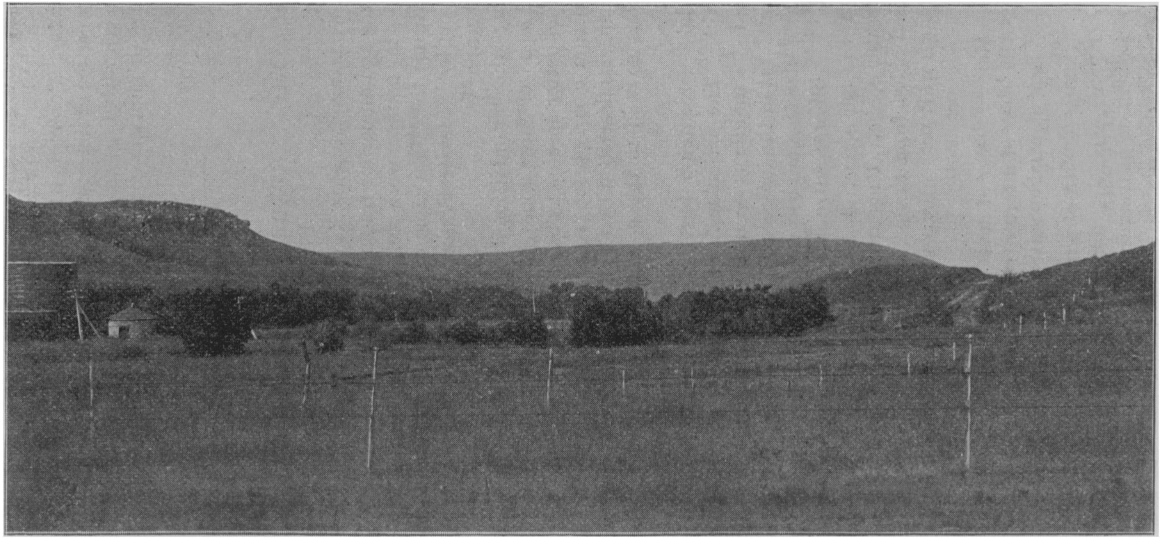
*From Univ. Geol. Surv. Kan., Vol. I.

†The valley of the Kansas river is lined in places on both sides with drift and loess, as are the valleys of some of the smaller streams.

‡The limestone in this section is exaggerated in order to be represented.

PLATE VIII.



(From University Geological Survey, Vol. II.)

DAKOTA SANDSTONE BLUFFS, SIX MILES WEST OF BROOKVILLE.

neous so far as our purposes here are concerned. The streams scarcely flow in their beds, and the country is monotonously level. The locality receives about five inches more rain per year than either of the first two, and five inches less than the third, farther to the northeast.* It has not been exposed to the weather longer than the third, and has received less rainfall. The abundance of vegetation is similar in the last two regions, save the fact that trees are almost wanting in Sumner county. Consequently we must attribute the great difference in topography to the presence of limestone in the one and the absence of it in the other.

Thus there is a varied topography, which difference of structure, together with slight difference of climatic conditions, has produced in a comparatively level plain.

NOTICE OF SOME VERTEBRATE REMAINS FROM THE KANSAS PERMIAN.

By S. W. Williston, Lawrence, Kan. Read before the Academy January 2, 1897.

Some months ago numerous fragments of bones, obtained from an excavation of a well in Cowley county, were sent me for examination by Mr. C. N. Gould. The horizon whence the bones came was clearly lower Permian, not far from its base, as accepted by Professor Prosser, the recognized authority on the Kansas Permian stratigraphy.

Not knowing whether additional material will be obtainable, I give here a description of some of these bones, which will be more fully illustrated in the future should no better specimens be secured.

An intercentrum clearly belongs to the genus *Cricotus*, and is closely allied to the typical species described by Cope from the Permian of Illinois.† His description applies so well to the specimen in hand that I use his language, amended:

"The caudal intercentrum best preserved is short, discoidal in form, and deeper than wide. The articular faces are deeply concave, the posterior more strongly so, and the middle is occupied by a foramen, whose diameter is about equal to one-half that of the intercentrum on either side. The lateral borders of the posterior articular face are less rounded than the anterior ones. The chevrons are slender and directed very obliquely backward, and their bases are firmly coössified with the intercentrum. On the superior surface two shallow pits occupy considerable space. They are separated by an obtuse ridge, and are bordered by a raised ridge from the polished layer of the lateral surface. Several phalanges of short, wide proportions show much resemblance to those of certain dinosaurs."

Diameter of intercentrum, vertical.....	18 mm.
Diameter of intercentrum, transverse..	17 "
Diameter of intercentrum, longitudinal,	11 "

Proximal width of phalanges..	12	12	13 mm.
Proximal depth of phalanges..	8	7	6 "
Length of phalanges..........	14	15	11 "

Another vertebra of smaller size doubtless represents a true centrum (see Cope, Trans. Amer. Phil. Soc., XVI, p. 245). It differs very materially in having remote sutural surfaces for the attachment of the neural arches, in being some-

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* Rep. Board Irr. Surv. and Exp. Kan. for 1895-'96, p. 195.

† Proc. Acad. Nat. Sci. Phila., 1875, p. 405.